PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 :
F01N 3/20

A1

(11) International Publication Number: WO 00/34631

(43) International Publication Date: 15 June 2000 (15.06.00)

(21) International Application Number: PCT/SE99/02090

(22) International Filing Date: 16 November 1999 (16.11.99)

(30) Priority Data:
9803990-2 20 November 1998 (20.11.98) SE

(71) Applicant (*for all designated States except US*): VOLVO PERSONVAGNAR AB [SE/SE]; S-405 08 Göteborg (SE).

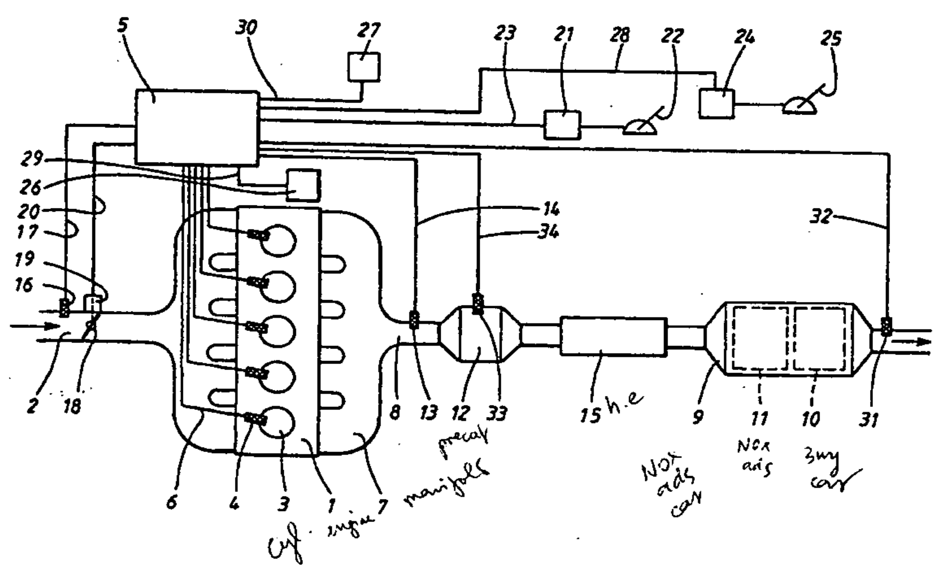
(72) Inventors; and
(75) Inventors/Applicants (*for US only*): LUNDGREN, Staffan [SE/SE]; Skidvägen 38, S-430 63 Hindås (SE). CLAESSON, Jacob [SE/SE]; Långlandia 1, S-414 53 Göteborg (SE). HANSSON, Maria [SE/SE]; Teknologgatan 5, S-411 32 Göteborg (SE). SANDBERG, Lars [SE/SE]; Torild Wulffsgatan 1A, S-413 19 Göteborg (SE). LARSSON, Mikael [SE/SE]; Västerängsgatan 9, S-431 44 Mölndal (SE).

(74) Agents: ANDERSSON, Per et al.; Albihns Patentbyrå Göteborg AB, P.O. Box 142, S-401 22 Göteborg (SE).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LT, LU, LV, MA, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
With amended claims.
In English translation (filed in Swedish).

(54) Title: HEAT EXCHANGER FOR SO_x– OR NO_x– REGENERATION OF CATALYST



(57) Abstract

The invention relates to a device for use with an internal combustion engine (1), comprising means (4, 5, 18) for generating an air/fuel mixture for the cylinders (3) of the engine (1), an exhaust system (7, 8) connected to the engine (1), and an NO_x–adsorbing catalytic converter (9) arranged in the exhaust system (7, 8). The invention is characterized in that it includes a heat exchanger (15) that is fitted upstream of the said catalytic converter (9) and is used to adapt the temperature of the exhaust gas from the engine (1) to the operating state of the catalytic converter (9) at the time. The device according to the invention ensures an improved exhaust system for a direct-injection (DI) engine, in which the temperature of the exhaust gas flowing through the said catalytic converter can be adapted to the operating state of the engine at the time.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

Heat exchanger for SO_x-or NO_x-regeneration of catalyst

TECHNICAL FIELD

The present invention relates to a device for use with an internal combustion engine, as specified in the pre-characterizing part of claim 1. In particular, the invention is intended for use with the exhaust system of an internal combustion engine, the exhaust system in question comprising an NO_x adsorber.

PRIOR ART

Vehicles operating with an internal combustion engine must meet the general requirement of a low level of harmful substances in the exhaust gas coming from the engine. These substances are predominantly compounds such as nitrogen oxides (NO_x), hydrocarbons (HC) and carbon monoxide (CO). In the case of modern petrol engines, the exhaust gas is normally purified with the aid of a catalytic converter, which is part of the exhaust system and through which the exhaust gas is passed. A "three-way catalyst" of the known type removes the predominant part of the above harmful compounds by means of the well-known catalytic reactions. To optimize the operation of the catalyst so that it gives the highest possible degree of purification as regards NO_x, HC and CO, the engine is run on a stoichiometric mixture of air and fuel, i.e. one with a lambda value (λ) of 1, in most operating modes.

Although modern three-way catalysts normally ensure a very high degree of purification and so greatly reduce the emission of harmful compounds into the atmosphere, there is nowadays a need for a further reduction in the emission of harmful substances. This is partly due to the ever more rigorous legislation introduced in various countries, stipulating an extremely low emission of NO_x, CO and HC compounds.

Furthermore, it is a general requir ment that vehicles should have th lowest possible fuel consumption. This has recently led to the development of

ngines with a n w type of combustion chamb r for the cylinders of the engine, especially to make it possible to run th engin on ever lean r fuel mixtures, i.e. on mixtures with a lambda value greater than 1. Such engines are generally called "lean-burn" engines. A direct-injection or DI engine, which is a spark-ignition engine with direct injection, can operate in a "stratified" manner, whereby the combustion chamber of the engine is so arranged that the fuel introduced into it can be concentrated to a great extent at the sparking plugs. When working in certain modes such as under a low or medium engine loading, such engines can run on very lean air/fuel mixtures, with a lambda value of the order of magnitude of 4. This gives a considerable fuel economy in the case of engines of this type. A direct-injection engine can also run in a "homogeneous" manner in certain modes of operation, mainly when driven under a high engine loading. The homogeneous operation corresponds to a stoichiometric (i.e. a relatively rich) air/fuel mixture being fed into the engine.

Since in certain modes of operation a direct-injection engine works on a very lean air/fuel mixture, the exhaust gas mixture that then flows through the three-way catalyst is also lean. This means that the three-way catalyst cannot reduce the NO_x compounds in the exhaust gas, because it is designed to give an optimum purification in the case of a stoichiometric mixture. To remedy this, the ordinary three-way catalyst can be combined with a nitrogen oxide adsorber, which is also called an NO_x adsorber or NO_x trap. The purpose of this in the known arrangement is to adsorb the NO_x compounds, e.g. from the exhaust gas of an internal combustion engine. These NO_x adsorbers can thus be installed and used in conjunction with the conventional three-way catalyst.

An NO_x adsorber can be arranged as a separate unit located upstream of the ordinary three-way catalyst, or alternatively it is integrated with the three-way catalyst, i.e. it is combined with the catalytic material in the three-way catalyst. The NO_x adsorber is so constituted that it takes up (adsorbs) the

NO_x compounds present in the xhaust gas of an engine when it is run on a lean air/fuel mixture, and it giv s off (desorbs) the NO_x compounds when the engine is being run on a rich air/fuel mixture for a certain time. Furthermore, the NO_x adsorber can only adsorb the NO_x compounds up to a certain limit, i.e. it gradually "gets full", with its adsorption capacity reaching its limit. When this happens, the NO_x adsorber has to be regenerated, which means that it must be made to desorb and so release the accumulated NO_x compounds. If there is a conventional three-way catalyst downstream of the NO_x adsorber, these desorbed NO_x compounds can be eliminated in the three-way catalyst, provided that the latter has reached its operating temperature.

According to the prior art, the NO_x adsorber can be regenerated by making the exhaust gas that passes through it relatively rich for a certain time. This in turn can be achieved by running the engine on a relatively rich air/fuel mixture for a short time, e.g. for a few seconds. This depletes the NO_x adsorber, so that it can then again adsorb NO_x compounds for a certain time before another regeneration becomes necessary. According to the prior art, the regeneration is achieved by controlling the concentration of air in the exhaust gas mixture flowing through the NO_x adsorber. Such a system is described in US Patent No. 5,461,857.

An NO_x adsorber is designed to operate at a certain temperature, which depends on the mode of operation of the engine at the time. During stratified operation, i.e. in the case of a lean air/fuel mixture, the temperature of the exhaust gas flowing through the NO_x adsorber lies in the range of about 200-500°C if an optimum operation of this adsorber is to be ensured. Furthermore, it is a general requirement that the exhaust gas temperature should not exceed about 800°C, because the NO_x adsorber may be ruined at higher temperatures.

A phenomenon that occurs in an NO_x adsorber is that the sulphur compounds, such as sulphur dioxide (SO_2), which are present in the xhaust

gas flowing through the NO_x adsorber form a deposit on the active material of the NO_x adsorber. With such a deposit on it, the NO_x adsorber cannot adsorb the NO_x compounds. The sulphur compounds come from the fuel and vary e.g. with the quality of the fuel. As a result of such a sulphur deposit, the adsorption capacity of the NO_x adsorber progressively decreases with time.

To solve the problem of this sulphur deposit, the NO_x adsorber must be regenerated at set intervals as regards the sulphur compounds as well, i.e. it must be freed from these compounds, so that the sulphur deposit on the NO_x adsorber can be removed. According to the prior art, such a sulphur regeneration can be carried out by running the engine for a certain time in such a way that a rich exhaust gas with a lambda value of less than 1 is produced and at the same time the exhaust gas has a relatively high temperature, specifically one in excess of about 650°C. In this way, the sulphur compounds are desorbed, i.e. they are discharged from the NO_x adsorber. According to the prior art, this sulphur regeneration is preferably done at intervals determined on the basis of how much of the NO_x storage capacity of the NO_x adsorber has been lost. This can in turn be estimated from the sulphur content of the fuel and the fuel consumption of the vehicle in question.

However, a problem that occurs in the prior art with the sulphur regeneration is that it is difficult to reconcile the desired exhaust gas temperature in the case of lean running, which is about 200-500°C, with the requirement that the temperature should be at least 650°C in the NO_x adsorber in order to be able to carry out a sulphur regeneration. This problem can be solved in principle by raising the exhaust gas temperature during the sulphur regeneration in the conventional manner, i.e. by delaying the ignition timing for the cylinders of the engine. However, this measure is not sufficient to raise the exhaust gas temperature to the required value if the vehicle in question is basically never run under a high engine loading, which happens in the case of certain types of drivers and certain types of driving situations.

It can therefore be concluded that a problem is presented by th conflicting requirements of a high temperature of at least 650°C for the sulphur regeneration on the one hand, and the relatively low temperature of about 200-500°C that prevails during the same type of operation but with a lean mixture. In addition, the temperature must be below about 800°C under all conditions, because otherwise the NO_x adsorber may stop working.

It should be possible to solve this problem by introducing a bypass construction into the exhaust system, whereby the exhaust gas can be passed along different routes through the exhaust system, depending on the temperature. However, this solution would require a costly valve arrangement, and such a separate valve arrangement in the exhaust system might also jeopardize the reliability of the latter.

DISCLOSURE OF THE INVENTION

The aim of the present invention is to provide an improved device for removing the harmful substances emitted by an internal combustion engine. In particular, the aim of the invention is to provide a device that ensures the right working temperature of an NO_x adsorber connected to an internal combustion engine. This aim is achieved with the aid of a device whose characterizing features are set out in claim 1.

The present invention relates to a device that comprises a means for generating an air/fuel mixture for the cylinders of the engine, an exhaust system connected to the engine, and an NO_x-adsorbing catalytic converter arranged in the exhaust system. The invention is characterized in that it also comprises a heat exchanger that is fitted upstream of the said catalytic converter and which is used to adapt the temperature of the exhaust gas from the engine to the operating state of the catalytic converter at the time.

Th present invention offers several advantages. First of all, the heat xchanger us d in conjunction with a direct-injection engine makes it possible to adapt the temperature of the exhaust gas flowing through the catalytic converter to match the mode of operation of the engine at the time. It should be mentioned here that the device according to the invention is a "passive system", which does not call for a separate valve arrangement or the like to effect this temperature adaptation. For the sulphur regeneration of the catalytic converter, one obtains here an exhaust gas temperature that lies in the range of about 650-800°C, which is needed for a satisfactory operation. Moreover, the use of the device according to the invention does not mean that the back pressure in the exhaust system is less favourable than in the conventional exhaust system, which would reduce the torque. Furthermore, the device according to the invention can be fitted in a vehicle with a relatively small available space and with a fully effective cooling surface area.

DESCRIPTION OF THE DRAWINGS

The invention is described below in more detail with reference to a preferred embodiment and the attached drawings, where:

Fig. 1 is an overall diagrammatic drawing showing the device according to the invention, connected to an internal combustion engine with which it can be used,

Fig. 2 is a perspective drawing of the heat exchanger used according to the invention,

Fig. 3 is a cross section through the heat exchanger, and

Fig. 4 shows the inlet of the heat exchanger in detail.

PREFERRED EMBODIMENTS

Fig. 1 shows a diagram of the device according to the present invention. In a preferred mbodiment, the d vice according to the inv ntion is connect d to

an internal combustion engine 1, which can be a conventional petrol engine or a diesel ngin , but is preferably a direct-injection or DI engine, i.e. an engine of the type of a spark-ignition engine with direction injection. In this case, the injection of the fuel into the engine 1 is designed for "stratified" operation, in which the fuel introduced can be concentrated in the combustion chamber of the engine. As a result, in certain predetermined modes of operation, the engine can run on a very lean air/fuel mixture having a lambda value of the order of magnitude of 4. Such an engine affords a significant fuel economy in comparison with engines run on a stoichiometric mixture, i.e. one with a lambda value of 1. However, such an engine is also suitable for "homogeneous" operation in certain modes of driving, where a stoichiometric or relatively rich air/fuel mixture is used. In the preferred case, the engine 1 performs a stratified operation when it is driven under a low or medium engine loading, and it performs a homogenous operation when it is driven under a relatively high engine loading.

The engine 1 is supplied with air through an air inlet 2 in the usual way. The engine 1 has a number of cylinders 3 and the corresponding number of fuel injectors 4. These injectors 4 are connected to a central control unit 5 via electrical connections 6. The control unit 5 is preferably a computerized device and is designed in the usual way for controlling the fuel supply to the injectors 4 from a fuel tank (not shown) in such a way that an appropriate air/fuel mixture is fed into the engine 1 at any given moment. In the preferred embodiment, the engine 1 is of the multi-point injection type, where the right amount of fuel can be supplied to the engine 1 in the known manner on an individual basis, via the corresponding injectors 4.

During the operation of the engine 1, the control unit 5 regulates the air/fuel mixture for the engine 1 in such a way that it is adapted at any given moment to the operating conditions prevailing at the time. The regulation of the engine 1 is essentially performed in the conventional way, i.e. on the basis of various parameters that reflect th operating conditions of the engin 1 and th

vehicle at the time. The engine can be regulated .g. on the basis of the current displacement of the accelerator, the number of revolutions of the engine per minute, the amount of air injected into the engine, and the concentration of oxygen in the exhaust gas at the time.

The engine 1 illustrated in the drawing has five cylinders, but it will be realized that the device according to the invention can also be used with engines having a different number of cylinders and different cylinder configurations. The injector 4 is preferably of the type that injects the fuel directly into the corresponding cylinder 3, but the device according to the invention can also be used with the "port injected" engines. Furthermore, the device according to the invention can also be employed with the "single-point" injection system, where a single fuel injector is placed in the inlet of the engine.

The exhaust gas of the engine 1 is led out of the cylinders 3 through an exhaust manifold 7 and then into an exhaust pipe 8 fitted to the exhaust manifold 7. Further downstream along the exhaust pipe 8 is located preferably an NO_x-adsorbing catalytic converter 9, composed of a conventional three-way catalyst 10 and an NO_x adsorber 11. The latter is of the conventional type and is so designed that it can adsorb the NO_x compounds flowing out of the engine 1 through the exhaust pipe 8. The catalytic converter 9 preferably contains a three-way catalyst 10 that is integral with the NO_x adsorber 11. This means that the catalytic converter 9 is an integrated unit comprising both an NO_x-adsorbing material and a noble metal that performs the function of a conventional three-way catalyst. This integrated unit is called below an "NO_x-adsorbing catalytic converter" or simply a "catalytic converter". Alternatively, the catalytic converter 9 can be arranged as a separate component, fitted in connection with the three-way catalyst 10. Irrespective of the embodiment in question, the NO_x adsorber 11 is shown in the drawing diagrammatically as a separate unit, using broken

lines. The exhaust gas then flows from the engine 1 through the xhaust pipe 8 and through the catalytic converter 9 into the atmosphere.

As mentioned before, the engine 1 can be a direct-injection engine, in which case the air/fuel mixture with a lambda value of the order of magnitude of 4 can be fed into the cylinders 3 during normal driving (stratified mode), using a lean air/fuel mixture. In the case of such a lean mixture, the NO_x compounds in the exhaust gas coming from the engine 1 are not reduced in the three-way catalyst 10, but are instead adsorbed by the NO_x adsorber 11.

In this embodiment, the engine 1 is also fitted with a pre-catalyst 12, which is located upstream of the catalytic converter 9. The pre-catalyst 12 is specially designed to ensure a quick catalyst warm-up when the engine 1 is started up from cold, that is to say, it is a unit whose catalytic layer becomes active quickly. This ensures a significant elimination of the HC, CO and NO_x compounds in the exhaust gas, especially in the case of a low exhaust rate on idling. By ensuring, with the aid of the pre-catalyst 12, that the exhaust gas passing through is warmed up quickly, one also obtains a relatively short heating-up time for the catalytic converter 9 downstream of it, this being the time that elapses before the catalytic converter 9 is warmed up to the temperature at which it can reduce a predetermined portion of the harmful substances in the exhaust gas. This ensures an effective purification of the exhaust gas from the engine 1, especially in the case of a cold start.

The system also contains a sensor 13 that detects the concentration of oxygen in the exhaust gas. The sensor 13 is preferably a linear lambda probe and is connected to the control unit 5 with the aid of an electrical connection 14. The sensor 13 is preferably placed in the exhaust pipe 8 at a point upstream of the pre-catalyst 12 but it can also be located in a different position, e.g. between the pre-catalyst 12 and the catalytic converter 9.

According to the invention, a heat exchanger 15 is inserted between the pre-catalyst 12 and the catalytic converter 9, the construction and operation of this unit being described below in detail. The main purpose of the heat exchanger 15 is to adapt the temperature of the exhaust gas flow so as to ensure the right working temperature for the catalytic converter 9 in the prevailing mode of operation of the engine 1 and the vehicle at the time.

In the device according to the invention, both the catalytic converter 9 and the pre-catalyst 12 have a predetermined oxygen storage capacity, so that they can take up and store a certain oxygen reserve. This construction of a three-way catalyst is part of the prior art and is based on the realization that, if the catalytic material can store a certain amount of oxygen, the catalytic reactions in the three-way catalyst (i.e. the oxidation of the hydrocarbons and the carbon monoxide and the reduction of the nitrogen oxides) can also take place when there is a certain excess of either air or fuel in the exhaust gas in comparison with the stoichiometric ratio, in which case the lambda value is 1. As described below in detail, the catalytic converter 9 is preferably made with an oxygen storage capacity that is much greater than that of the pre-catalyst 12. More specifically, the ratio between the oxygen storage capacity of the pre-catalyst 12 and that of the catalytic converter 9 is at least 1:2 and preferably between 1:5 and 1:30.

An air flow-meter 16 is fitted in the air inlet 2. This is a conventional air flow-meter that is connected to the control unit 5 via a separate connection 17 and which gives a signal proportional to the amount of air flowing into the engine 1. The system also contains a butterfly valve 18 for the fuel setting, which is preferably operated electrically. For this purpose, the butterfly valve 18 is equipped with an adjustable actuating motor 19, with the aid of which the valve can be placed in the desired position. This ensures that a suitable amount of air is fed into the engine 1, according to the mode of operation at the time. The actuating motor 19 is coupled to the control unit 5 with th aid of a separate connection 20. To control th butterfly valv 18 for the fuel

setting, the system also incorporates a position sensor 21 for the accelerator pedal 22. This position sensor 21 senses the position of the accelerator pedal 22 and sends a signal to the control unit 5 via a separate connection 23 according to its position, i.e. it sends a signal the value of which corresponds to the current displacement of the accelerator.

Furthermore, the control unit 5 is connected to a number of additional sensors, which are shown diagrammatically in Fig. 1. These preferably include a position sensor 24 to sense the position of the brake pedal 25 of the vehicle, a speed sensor 26 that detects the number of revolutions of the engine 1 per minute, and a pressure sensor 27, which detects the pressure in the brake booster of the vehicle (not shown). These sensors 24, 26 and 27 are coupled to the control unit 5 via the corresponding electrical connections 28, 29 and 30.

The system preferably also comprises an NO_x sensor 31, which detects the concentration of the NO_x compounds in the exhaust gas. The NO_x sensor 31 is coupled to the control unit 5 with the aid of a separate electrical connection 32. The NO_x sensor 31 can be placed in various positions in the exhaust system, e.g. between the pre-catalyst 12 and the catalytic converter 9, or downstream of the catalytic converter 9, as shown in the drawing. Furthermore, there is preferably also a temperature sensor 33, connected to the pre-catalyst 12. The temperature sensor 33 is coupled to the control unit 5 with the aid of a separate electrical connection 34 and gives a signal that reflects the temperature of the pre-catalyst 12. The signal from the temperature sensor 33 can also be used as a measure of the temperature of the catalytic converter 9. As an alternative to the temperature sensor 33 or in addition to it, a measure of the temperature of the catalytic converter 9 can be obtained furthermore by using a predetermined mathematical model that is stored in the control unit 5 in advance. For example, such a model can use a pre-established connection between the temperature of th pre-catalyst 12 and that of the catalytic converter 9. Alternatively, a temperature sensor can

be fitted in som oth r position along the exhaust pip , for exampl between the pre-catalyst 12 and the heat exchanger 15. The temperature sensor then gives a signal that is proportional to the temperature of the exhaust gas flowing through the exhaust pipe 8.

Fig. 2 is a perspective drawing of a heat exchanger 15 according to the invention. In the embodiment under consideration, this heat exchanger is in the form of an elongated unit with an inlet 25, an outlet 36 and a number of straight cooling tubes 37. The heat exchanger 15 is so constructed that the exhaust gas from the engine enters its inlet 35, passes through the cooling tubes 38 and exits at the outlet 36, the direction of flow being indicated by the arrows in the drawing. When the tubes 37 are viewed in cross section, it can be seen that they are preferably arranged in such a way that their centres essentially lie on a circle. In this embodiment, there are seven tubes 37, but there can also be fewer or more of them within the scope of the invention. The number, diameter and length of these tubes are chosen on the basis of e.g. the amount and flow rate of the exhaust gas. Other factors that affect the location and dimensions of the tubes 37 are the space available in the vehicle in question, the desired back pressure, and the necessary cooling surface area of the heat exchanger 15. The tubes 37 are made of stainless steel or a material with similar properties.

In this embodiment, all the tubes 37 essentially have the same dimensions, so that the exhaust gas flowing through them can be distributed essentially equally among them. Furthermore, since the tubes 37 are positioned on a circle, as can be seen especially in Fig. 3, which is a cross section taken through the heat exchanger 15 at a point between its inlet 35 and outlet 36, the temperature of each individual tube 37 is essentially the same during operation. This means in turn that thermal stresses are avoided, because all the tubes are exposed to the same amount of radiating heat from the exhaust gas and heat from the adjacent tubes.

Fig. 4 shows the inlet 35 of the heat exchanger in detail. This inlet 35 comprises an inlet cone 38 through which th exhaust gas flows in. This inlet cone 38 is welded to a cap 39, which is in turn provided with orifices for fixing the tubes 37 in them. The inside of the cap 39 has a part that is convex towards the entering exhaust gas, which ensures that the latter is distributed essentially equally among the tubes 37. For this purpose, the convex part is given an essentially hemispherical shape. This ensures that the same amount of gas flows into each tube, which in turn means that the temperature of the gas is essentially the same in all the tubes. This arrangement also permits a relatively low back pressure in the heat exchanger 15, which is an advantage. Another advantage of this arrangement is that it minimizes the ineffective cooling surface area, which in turn reduces the weight and cost of the unit. In addition, the possible effect of the radiating heat from the adjacent tubes is reduced.

The outlet 36 of the heat exchanger 15 is so constructed that it is identical to its inlet 35 (see Fig. 2), which gives a cost advantage, since fewer different components are then needed for the heat exchanger 15.

The following description shows how the NO_x regeneration and the SO_x regeneration can be effected with the aid of the device according to the invention. When the engine 1 is a direct-injection engine, it can be run on a very lean air/fuel mixture during normal continuous driving, more specifically on a mixture with a lambda value of the order of magnitude of 4. This means that the exhaust gas flowing through the exhaust pipe 8 and the catalytic converter 9 is also lean. It is well known that the catalytic converter 9 then adsorbs the NO_x compounds that are present in the exhaust gas. After operating with the lean exhaust gas for a certain time, normally for about 1-2 minutes, however, the catalytic converter 9 "gets full", i.e. its catalytic material becomes saturated. As a result, the catalytic converter 9 cannot take up any more NO_x compounds from the exhaust gas, and it must therefore be r generated at this point in time. The NO_x regeneration is done according to

the conventional method by passing a relatively rich exhaust gas mixture through th catalytic converter 9 for a certain tim . This relativ ly rich exhaust gas is obtained by running the engine 1 on a relatively rich air/fuel mixture for a certain time, for example for a few seconds, under the guidance of the control unit 5. This leads to the desorption of the NO_x compounds that have so far been adsorbed by the catalytic converter 9, so that the latter can again adsorb the NO_x compounds for a certain time, before another regeneration becomes necessary. When the NO_x compounds have been desorbed from the catalytic converter 9, they can also be reduced with the aid of the catalyst layer that forms an integral part of the catalytic converter 9.

As mentioned in the introduction, the sulphur compounds eventually deposit on the catalytic converter 9 and so prevent the latter from adsorbing any NO_x compounds. For this reason, a sulphur regeneration is carried out by using up a certain amount of the oxygen stored in the oxygen reserve of the catalytic converter 9 for burning. More specifically, first the uncombusted hydrocarbons in the exhaust gas are burned off in the catalytic converter 9 with the aid of the oxygen stored in the oxygen reserve while the engine 1 is being operated in such a way that a rich exhaust gas is being produced. In this way, heat is generated while the oxygen reserve is being gradually depleted. When the oxygen reserve has been depleted at least in part, the engine 1 is switched over to another mode of operation, in which it generates instead a relatively lean exhaust gas, i.e. one with an oxygen excess. This makes it possible to store a new quantity of oxygen in the oxygen reserve of the catalytic converter 9. The engine 1 then again switches over to rich running, as a result of which the process is repeated, and the oxygen reserve of the catalytic converter 9 is depleted, which is accompanied by heat production. The heat production that occurs during the repeated burning of the uncombusted hydrocarbons raises the temperature of the exhaust gas above about 650°C, above which temperature sulphur regeneration can take place. The heat exchanger 15 helps to limit the temperature of the exhaust

gas, so that it does not exceed about 800°C, above which the catalytic converter 9 may be ruined.

The above alternating process continues for a certain time, according to how much of the sulphur accumulating in the catalytic converter 9 has been eliminated. This period can be estimated from the sulphur content of the fuel used in the engine 1 and the fuel consumption of the vehicle in question, and these parameters are stored in the control unit 5. For this purpose, the signal from the temperature sensor 33 can also be used in conjunction with some algorithms stored in the control unit 5 in advance. These algorithms define a correlation between the temperature measured by the temperature sensor 33 and the temperature prevailing in the catalytic converter 9. These algorithms take into account for example the amount of oxygen stored in the catalytic converter 9 and the length of the period during which the uncombusted hydrocarbons are burned off in the catalytic converter 9 in the process described above. In this way, the control unit 5 can be used for fixing the amount of heat produced in the catalytic converter 9, as well as for checking whether the temperature in the catalytic converter 9 has exceeded the value of about 650°C for a sufficiently long time to ensure that sulphur regeneration takes place.

A similar burning process with stored oxygen occurs also in the pre-catalyst 12 during operation with a rich exhaust gas. According to what was said above, the oxygen storage capacity of the pre-catalyst 12 is much lower than that of the catalytic converter 12. As a result, only a small part of the uncombusted hydrocarbons released from the engine 1 is burned in the pre-catalyst 12. The greater part of the uncombusted hydrocarbons instead travels along the exhaust pipe 8 and is burned off in the catalytic converter 9. This means that the main heat production occurs where it is actually needed, i.e. in the catalytic converter 9. This ensures the effective sulphur regeneration of the catalytic converter 9.

Th sulphur regeneration proc ss is described b low in detail. It is assumed here that the NO_x regeneration of the catalytic converter proceeds continuously. In the preferred embodiment, the engine 1 is a direct-injection engine that is designed in such a way that it produces a relatively lean exhaust gas in a certain mode of operation, e.g. when the vehicle is driven continuously under a medium high engine loading. During such an operation, the system checks whether a sulphur regeneration is necessary. For this purpose, the control unit 5 is designed to determine the value of the lost NO_x storage capacity of the catalytic converter 9, which can be done on the basis of e.g. the sulphur content of the fuel used in the engine 1, the fuel consumption of the vehicle, and the time elapsing since the last regeneration.

When the NO_x storage capacity of the catalytic converter 9 falls below a predetermined value, a sulphur regeneration must be carried out. To initiate this process, the control unit 5 adjusts the air and fuel supply to the engine in such a way that a rich mixture is obtained. The fuel supply to the injectors 4 is adjusted to obtain the required mixture, depending also on the other operational parameters of the engine, e.g. the current displacement of the accelerator, the number of revolutions of the engine per minute, and the amount of air injected into the engine. In such a way, the engine 1 is switched over to a mode of operation in which a rich exhaust gas, having a lambda value of under 1, flows through the catalytic converter 9. As explained before, the result of this is that the stored oxygen in the oxygen reserve of the catalytic converter 9 is used for burning off the uncombusted hydrocarbons in the exhaust gas flow. This leads to heat production, which raises the temperature of the exhaust gas flow and the catalytic converter 18 to at least about 650°C.

Under the conditions prevailing during the normal driving of a car, the oxygen reserve in the catalytic converter 9 is depleted after a few seconds of operation with a rich exhaust gas. When this happens, the control unit 5 switch s the engine 1 ov r to a mode in which it is suppli d with a relatively

lean air/fuel mixture and so produces a r lativ ly lean xhaust gas mixture, with a lambda value of over 1, for the catalytic converter 9. In this way, the exhaust gas acquires an excess of oxygen, so that a new quantity of oxygen is stored in the oxygen reserve of the catalytic converter 9. The control unit 5 then checks whether a sufficient consumption of the stored oxygen in the catalytic converter 9 has taken place, i.e. whether a sufficiently extensive sulphur regeneration has occurred to consider that the catalytic converter 9 has recovered its NO_x storing capacity. If the sulphur regeneration is considered to be sufficient, the engine is allowed to return to its original mode of operation, using a lean mixture. If the sulphur regeneration is not considered to be sufficient, the engine is switched over to operate with a rich mixture, and so the above process of alternating rich and lean exhaust gases in the catalytic converter 9 is repeated.

The time needed to ensure a complete sulphur regeneration of the catalytic converter 18 depends on various factors, such as for example the sulphur content of the fuel used in the engine 1, the fuel consumption of the vehicle, the size of the catalytic converter 18, the magnitude of the oxygen reserve in the latter, and the extent of the previous sulphur regeneration steps.

It has been assumed in the above description of the process that the oxygen reserve of the catalytic converter 9 is in principle fully depleted when the engine produces a rich exhaust gas mixture. During the following operation producing a lean exhaust gas, a certain amount of oxygen accumulates in the oxygen reserve of the catalytic converter 9, so that this reserve is partly replenished. The process is then again switched to an operation that produces a rich exhaust gas. In an alternative, reversed sequence of events, the mode of operation with a lean exhaust gas leads to a basically complete restoration of the oxygen reserve, while the mode of operation with a rich exhaust gas mixture leads to the consumption of only part of the oxygen reserve for burning.

The consumption of the oxyg n r serv of the catalytic converter 9 for combustion can also be used in combination with other measur s for raising the temperature of the exhaust gas, for example with a delayed ignition of the fuel in the cylinders 3 in question.

As an alternative to the operation described above, the exhaust system can also be designed in such a way that a partial SO_x regeneration of the catalytic converter 9 takes place, i.e. a regeneration that does not necessary continue until the catalytic converter 9 is completely free of sulphur compounds. This may be relevant for example when a certain mode of operation means that a relatively rich air/fuel mixture can be supplied to the engine only for a certain time. However, the control unit 5 is designed to store the value for the sulphur deposit continuously, which then acts as the basis of the next regeneration of the catalytic converter 9.

The above NO_x regeneration is preferably initiated when at least one of the predetermined operating situations prevails. An example of such an operating state that can be used according to the invention is one that corresponds to a deliberate change in the torque of the engine 1. This operating state can come about e.g. as a result of the driver's behaviour, such as displacing the accelerator by a certain amount. When the driver wants to overtake, for example, and therefore opens the throttle more, the vehicle accelerates. In the well-known manner, the control unit 5 sends a relatively rich air/fuel mixture to the engine 1 when the vehicle is to accelerate. For example, the engine 1 can be so designed that it delivers its maximum torque when fed with an air/fuel mixture having a lambda value of 0.9. During acceleration, the driver expects the torque delivered by the engine to increase. This state can be simultaneously utilized for the full or partial regeneration of the NO_x adsorber. For this purpose, the control unit is so designed that, when this state is detected, it ensures the flow of a relatively rich exhaust gas mixture to the NO_x adsorber for a certain time, so that th d sired regen ration of the NO_x adsorber can take place. This is an

advantage from the point of view of driving comfort, because the driver then does not experience any drawback if, simultaneously with the acceleration, a "pulse" of a rich exhaust gas is produced for the regeneration of the NO_x adsorber. In addition, there is also an advantage as regards the fuel consumption of the vehicle, since a change in the torque of the engine 1 brought about in any case is utilized for the regeneration.

The control unit is preferably so designed that it checks during the operation whether any one of a number of predetermined operating conditions exists. The aim of this is to permit the regeneration of the NO_x adsorber when at least one of these operating conditions prevails. Thus, the control unit 5 is designed to detect whether a state that corresponds to a deliberate change in the torque in the form of a "driver-activated NO_x regeneration" prevails, and if it does, then it generates a "pulse" of a rich exhaust gas. This means that the control unit 5 can detect the angular position of the accelerator pedal 22 with the aid of the position sensor 21. If the displacement of the accelerator exceeds a predetermined limit, i.e. if the opening of the butterfly valve 18 for the fuel setting exceeds a certain limit, the control unit 5 assumes that a "driver-activated NO_x regeneration" is taking place. In such a case, the control unit 5 chooses an appropriate composition for the air/fuel mixture that is to be fed into the engine to enable the regeneration of the NO_x adsorber to take place. Normally a relatively rich mixture is chosen here, e.g. one with a lambda value of the order of magnitude of 0.7-0.8. This mixture should be retained for a certain time t_1 that is necessary for the full regeneration of the catalytic converter. The value of the time t_1 that corresponds to the state in question can be based on empirical measurements and is determined by the control unit 5. As explained below in detail, this time t_1 can be set at a value between a few tenths of a second and a few seconds.

After the control unit has calculated the appropriate lambda value for the regeneration and the value of time t_1 during which the regeneration is to take place, it initiates th regeneration by sending an air/fuel mixture to the engine

1 such that gives the calculated rich exhaust mixture for the calculated time. The fuel supply is sent here to the injectors 4 shown in Fig. 1 so that the desired mixture is obtained, depending also on e.g. the amount of air supplied to the engine. This pulse of a rich exhaust gas is generated simultaneously with the acceleration by the driver. The driver then does not notice any difference as regards driving comfort when the catalytic converter is regenerated at the same time, which is an advantage.

The length of the time t_1 needed for the complete regeneration of the catalytic converter 9 depends on various operating parameters, such as the number of revolutions of the engine 1 per minute, the engine loading, and the degree of filling of the catalytic converter 9 at the time. The control unit can be set for the continuous determination of a value of this degree of filling on the basis of various known parameters giving the size of the catalytic converter 9 and the speed with which it gets full during lean operation. In this way, the regeneration can be limited to the time that is effectively needed for the NO_x compounds to be essentially removed. If, for example, at a given moment when the "driver-activated regeneration" is detected, the catalytic converter 9 is half full of NO_x compounds and so has a degree of filling of 50%, a relatively small value can be chosen for the time t_1. If on the other hand, the NO_x adsorber shows a degree of filling that is in principle 100%, then a relatively high value has to be chosen for the time t_1 to ensure a complete regeneration of the NO_x adsorber.

The "driver-activated NO_x regeneration" described above is an example of how the catalytic converter 9 can be regenerated as a result of a deliberate change in the torque of the engine 1. Other examples of a deliberate change in torque that can be utilized for the NO_x regeneration are the activation of the cruise control mechanism (if there is one in the vehicle), the switching on and off of the air conditioning system, the switching on and off of a system regulating the stability of the vehicle, the activation of a wheel anti-spin system, and the activation of a purge function of an exhaust canister used to

accommodate the fuel vapours from the fuel tank of the vehicle. All these measures lead to a change in torque with which the regeneration of the catalytic converter 9 can be carried out.

Another state or condition that can be detected and utilized for the NO_x regeneration of the catalytic converter is the extent to which a certain predetermined pressure prevails in the brake booster of the vehicle. Modern vehicles are normally equipped with a brake booster, which comprises a vacuum chamber with a connection to the engine inlet, so that a negative pressure can be generated in the vacuum chamber during the operation of the engine. This pressure is utilized to ensure the required braking force applied by the brake system. The abovementioned pressure sensor 27 shown in Fig. 1 is then used to measure this pressure. If the pressure value is different from a predetermined limit, the engine is adjusted in such a way that the air-fuel quantity is changed in order to ensure the desired pressure at the engine inlet. If this situation is detected by the control unit, an NO_x regeneration is also initiated in this embodiment, whereby the control unit calculates an appropriate lambda value and time period during which a pulse of rich exhaust gas should be present in the catalytic converter. In this way, the invention additionally fulfils an automatic control function, since it guarantees that a predetermined pressure prevails in the brake booster.

The NO_x regeneration can also be controlled according to the position of the brake pedal 25 of the vehicle, using the position sensor 24 connected to the brake pedal 25. If, for example, the driver applies the brakes, this situation can be utilized to initiate the said regeneration. As an alternative to detecting the position of the brake pedal 25, the system can use a signal from a pressure sensor (not shown), which senses the braking pressure prevailing in the brake circuit of the vehicle.

The abovementioned operating conditions of the engine and the vehicle can be described as "prevailing" op rating conditions or stat s that can arise in

the vehicl during its normal operation, and which mean that the air/fuel mixture supplied to the engine must be altered. These operating conditions can then be utilized for the simultaneous initiation of an NO_x regeneration of the catalytic converter 9.

As an alternative to the method of operation described above, a partial NO_x regeneration of the catalytic converter 9 can also be performed, i.e. one that need not continue until the catalytic converter has been completely freed of the NO_x compounds. This may be relevant e.g. when a certain operating mode of the vehicle dictates that a relatively rich air/fuel mixture can be supplied to the engine only for a certain limited time. In such a case, the catalytic converter is only partly freed of the NO_x compounds. However, the control unit is designed for the continuous storage of a value of the degree of filling, which then acts as the basis of the next NO_x regeneration of the catalytic converter 9.

If none of the above operating conditions is present, the catalytic converter 9 must still be given an NO_x regeneration when it is full. If for example the vehicle in question is driven for a fairly long time without any acceleration (i.e. without any "driver-activated NO_x regeneration" taking place), the catalytic converter 9 must be compulsorily regenerated when it is full. This corresponds to a regeneration after a certain maximum time has elapsed since the last regeneration. If such a time t_2 elapsing since the last regeneration exceeds a certain limit, which can be identified by the control unit, a regeneration must be carried out compulsorily. The system then proceeds to determine an appropriate lambda value and time t_1 during which a pulse of rich exhaust gas should be sent into the catalytic converter 9, whereupon regeneration takes place.

As regards the calculation of the lambda value and the time t_1 during which a pulse of rich exhaust gas should be present, the fact is that these two parameters can vary with the operating modes of the vehicle. For example, a

pulse of rich exhaust gas with a relatively high lambda value of e.g. 0.9 can be utilized if the driver presses the accelerator down hard. Other lambda values can be used in other operating situations, depending also on e.g. which signal is used or on the catalyst in use, etc. Furthermore, in all the above operating conditions, the lambda value and the time t_1 can be determined according to the degree of filling of the catalytic converter 9 at the time, i.e. according to how extensive a regeneration is required at the moment. Moreover, a relatively high lambda value may call for a longer time t_1 than a lower lambda value. In most cases, the time t_1 can be approximately between 0.5 and 5 seconds.

The temperature of the pre-catalyst can also be used for determining the lambda value and the time t_1. For this purpose, it is possible to feed into the control unit some tabulated values giving the corrections for the lambda value and/or the time t_1 according to the temperature value measured with the aid of the temperature sensor 33 shown in Fig. 1, possibly in combination with a software-based estimation of the temperature of the catalytic converter 9, as described above.

The NO_x regeneration of the catalytic converter 9 can also be carried out by weighting several parameters that indicate how much the regeneration is necessary. In such a case, the control unit first senses whether one or more of the above operating conditions apply. If this is the case, then a "collective weighing" is carried out by calculating a sum where each observed condition is given a weighted value that is added to this sum. If the sum exceeds a certain predetermined limit, the control unit assumes that a regeneration of the catalytic converter is necessary, and so a pulse of rich exhaust gas is generated.

According to the invention, the abovementioned heat exchanger 15 is used, which is preferably located upstream of the NO_x-adsorbing catalytic converter 9. The heat exchang r 15 acts here as a passive component, with the aid of

which the t mperature of th exhaust gas from the engine 1 is adapted to the prevailing operating stat of th vehicl in qu stion, so as to ensure an optimum operation of the catalytic converter 9, whereby the emission of harmful substances from the engine 1 is reduced as much as possible. For example, in the operating state in which the engine 1 is driven in the homogeneous mode, a relatively hot exhaust gas is obtained from the engine 1, i.e. an exhaust gas whose temperature can reach about 950°C. In this situation, the device according to the invention ensures that the exhaust gas is cooled by the heat exchanger 15. Owing to the construction of the heat exchanger 15 described above, the temperature of the exhaust gas in this state is reduced to a level where it is not harmful for the catalytic converter 9, i.e. to a value of below about 800°C. In this operating state, the atmospheric air also contributes to the cooling of the exhaust gas during driving. Furthermore, the heat exchanger 15 is so designed that the exhaust gas temperature during the sulphur regeneration lies between about 650 and 800°C. In the corresponding operating state but with a lean operation of the engine 1, it is also ensured by the device according to the invention that the exhaust gas temperature is about 200-500°C. In this way, the device according to the present invention solves the conflict between the need for a relatively high exhaust gas temperature in the catalytic converter 9 during the sulphur regeneration, and a relatively low exhaust gas temperature during lean operation. This is particularly true, since the temperature of the exhaust gas coming directly from the engine 1 in the case of e.g. stratified operation is relatively low. Despite this, the device according to the invention ensures that the exhaust gas is not cooled so much as to reduce this temperature to below about 200°C.

The invention is not limited to the embodiments described above and illustrated in the drawings but can be modified within the scope of the claims that follow. For example, the pre-catalyst may be an electrically heatable start-up catalyst. Furthermore, the invention can be used both with a conventional butterfly valve for th gas setting and with an electrically

controlled one. Furthermore, the invention can be used in conjunction with engines that are fitted with a turbo-charger.

The components such as the temperature sensor 33, for example, can be placed at sites that are different from the positions described above. For example, the temperature sensor can be located downstream of the catalytic converter 9. In this way, it is possible to check whether the exhaust gas temperature has reached the lower limit of 650°C for sulphur regeneration.

CLAIMS

1. Device for use with an internal combustion engine (1), comprising means (4, 5, 18) for generating an air/fuel mixture for the cylinders (3) of the engine (1), an exhaust system (7, 8) connected to the engine (1), and an NO_x-adsorbing catalytic converter (9) arranged in the exhaust system (7, 8), characterized in that it includes a heat exchanger (15) that is fitted upstream of the said catalytic converter (9) and is used to adapt the temperature of the exhaust gas from the engine (1) to the operating state of the catalytic converter (9) at the time.

2. Device according to claim 1, characterized in that the said heat exchanger (15) consists of a number of essentially identically shaped tubes (37), which are traversed by the exhaust gas from the engine (1) and are mounted essentially parallel to one another and whose centres, seen in cross section, are essentially arranged on a circle.

3. Device according to claim 1 or 2, characterized in that it includes a control unit (5) that is designed to regulate the said means (4, 5, 18) in order to induce the repeated NO_x regeneration and SO_x regeneration of the catalytic converter (9).

4. Device according to claim 3, characterized in that the control unit (5) is designed to set the said means (4, 5, 18), in a first operating mode, for generating a relatively lean exhaust gas mixture for the NO_x adsorber (11) in order to cause the adsorption of the NO_x compounds present in the said exhaust gas mixture, and to set the said means (4, 5, 18), in a second operating mode, for generating a relatively rich exhaust gas mixture for the said NO_x adsorber (11) in order to cause the desorption of the NO_x compounds present in the said exhaust gas mixture.

5. Device according to claim 4, characterized in that the control unit (5) can also detect whether at least one condition is present in the vehicle, which condition corresponds to an initiation of a change from the said first operating mode to the said second operating mode, in which case there is a change-over in the said air/fuel mixture for the engine (1), and so the said generation of a rich exhaust gas is initiated for the desorption of the NO_x compounds in the NO_x adsorber (11), according to the said state.

6. Device according to claim 5, characterized in that the said state corresponds to a deliberate change of the torque of the said engine (1).

7. Device according to any one of claims 3-6, characterized in that the control unit (5) is designed for the alternating regulation of the internal combustion engine (1), i.e. alternating between a first state, in which a relatively rich exhaust gas mixture is fed into the catalytic converter (18) whereupon the oxygen reserve in the catalytic converter (18) is at least partly used up for the combustion of hydrocarbons in the exhaust system (16, 17) to generate heat, and a second state, in which a relatively lean exhaust gas mixture is fed into the catalytic converter (18) to replenish the oxygen in the said oxygen reserve, and in that the control unit (5) is designed to stop the said alternating regulation after a predetermined amount of sulphur compounds has been desorbed from the said catalytic converter (18).

8. Device according to any one of the previous claims, characterized in that the said engine (1) is a direct-injection (DI) spark-ignition engine.

AMENDED CLAIMS

[received by the International Bureau on 11 April 2000 (11.04.00); original claims 1 to 8 replaced by new claims 1 to 9 (2 pages)]

1. Device for use with an internal combustion engine (1) of the "lean-burn" engine type, comprising means (4, 5, 18) for generating an air/fuel mixture for the cylinders (3) of the engine (1) in order to provide at least stratified and homogenous operation, an exhaust system (7, 8) connected to the engine (1), and an NO_x-adsorbing catalytic converter (9) arranged in the exhaust system (7, 8), characterized in that it includes a heat exchanger (15) that is fitted upstream of the said catalytic converter (9) and is used to adapt the temperature of the exhaust gas from the engine (1) to the operating state of the catalytic converter (9) at the time.

2. Device according to claim 1, characterized in that said means (4, 5, 18) are adapted for sulphur regeneration of the catalytic converter (9) by repeatedly burning of oxygen in an oxygen reserve in the catalytic converter (9) together with uncombusted hydrocarbon compounds in the exhaust gases from the engine (1), so as to raise the temperature of said exhaust gases.

3. Device according to claim 1 or 2, characterized in that the said heat exchanger (15) consists of a number of essentially identically shaped tubes (37), which are traversed by the exhaust gas from the engine (1) and are mounted essentially parallel to one another and whose centres, seen in cross section, are essentially arranged on a circle.

4. Device according to any one of claims 1-3, characterized in that it includes a control unit (5) that is designed to regulate the said means (4, 5, 18) in order to induce the repeated NO_x regeneration and SO_x regeneration of the catalytic converter (9).

5. Device according to claim 4, characterized in that the control unit (5) is designed to set the said means (4, 5, 18), in a first operating mode, for generating a relatively lean exhaust gas mixture for the NO_x adsorber (11) in

order to cause the adsorption of the NO_x compounds present in the said exhaust gas mixture, and to set the said means (4, 5, 18), in a second operating mode, for generating a relatively rich exhaust gas mixture for the said NO_x adsorber (11) in order to cause the desorption of the NO_x compounds present in the said exhaust gas mixture.

6. Device according to claim 5, characterized in that the control unit (5) can also detect whether at least one condition is present in the vehicle, which condition corresponds to an initiation of a change from the said first operating mode to the said second operating mode, in which case there is a change-over in the said air/fuel mixture for the engine (1), and so the said generation of a rich exhaust gas is initiated for the desorption of the NO_x compounds in the NO_x adsorber (11), according to the said state.

7. Device according to claim 6, characterized in that the said state corresponds to a deliberate change of the torque of the said engine (1).

8. Device according to any one of claims 4-7, characterized in that the control unit (5) is designed for the alternating regulation of the internal combustion engine (1), i.e. alternating between a first state, in which a relatively rich exhaust gas mixture is fed into the catalytic converter (18) whereupon the oxygen reserve in the catalytic converter (18) is at least partly used up for the combustion of hydrocarbons in the exhaust system (16, 17) to generate heat, and a second state, in which a relatively lean exhaust gas mixture is fed into the catalytic converter (18) to replenish the oxygen in the said oxygen reserve, and in that the control unit (5) is designed to stop the said alternating regulation after a predetermined amount of sulphur compounds has been desorbed from the said catalytic converter (18).

9. Device according to any one of the previous claims, characterized in that the said engine (1) is a direct-injection (DI) spark-ignition engine.

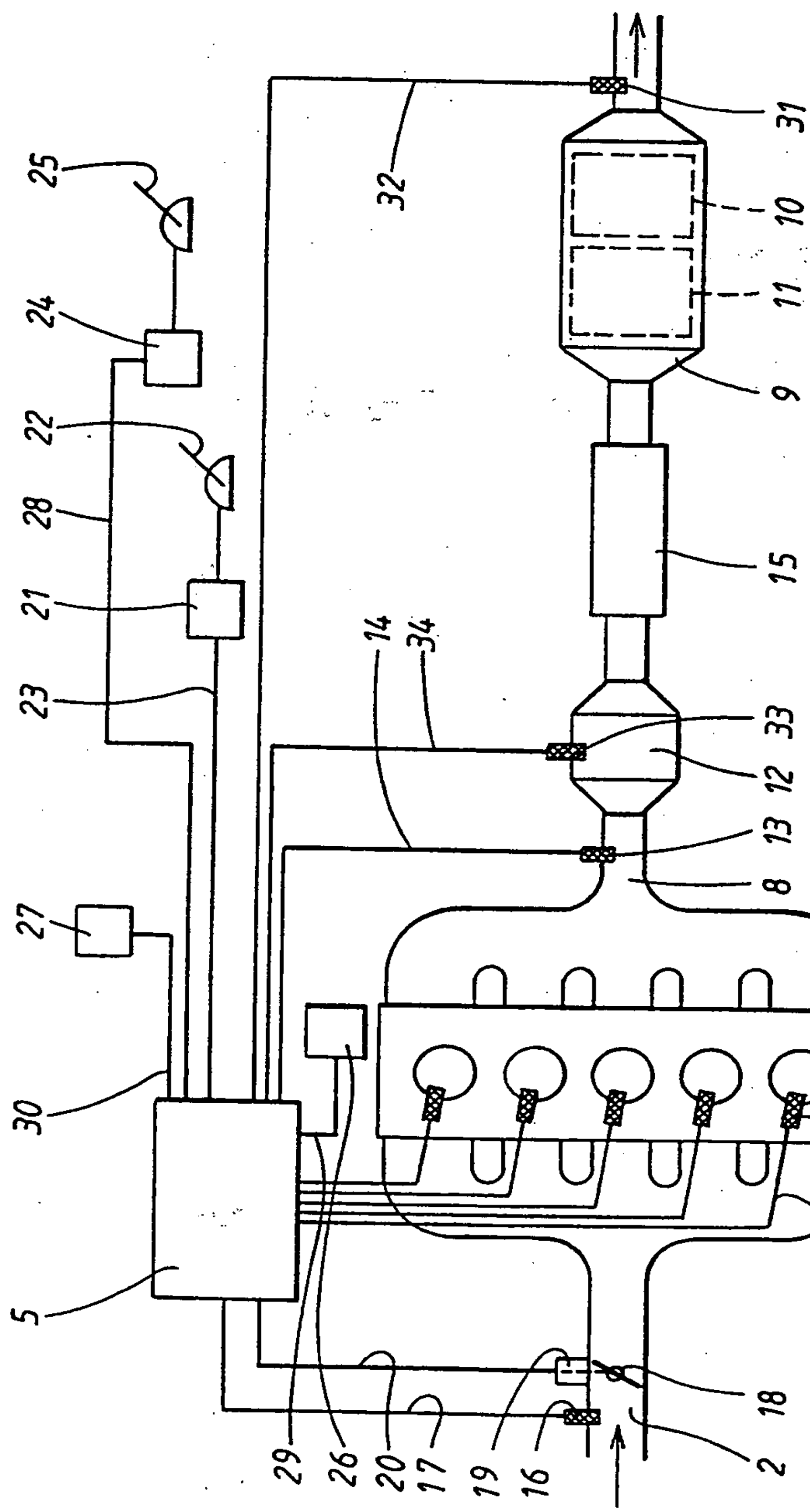

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

FIG. 1

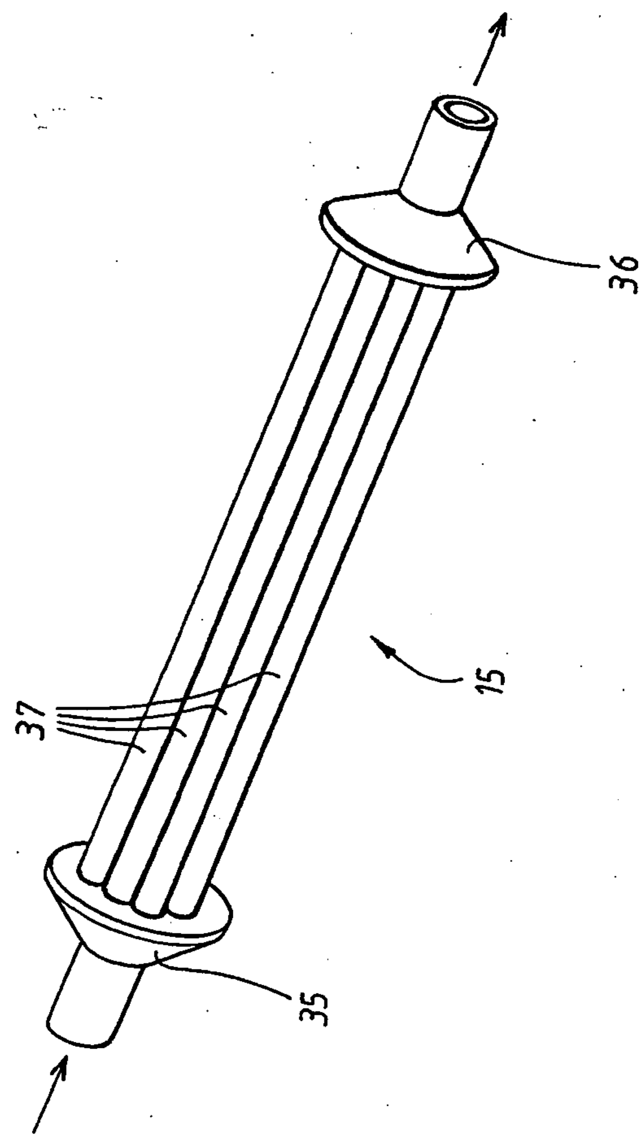


FIG. 2

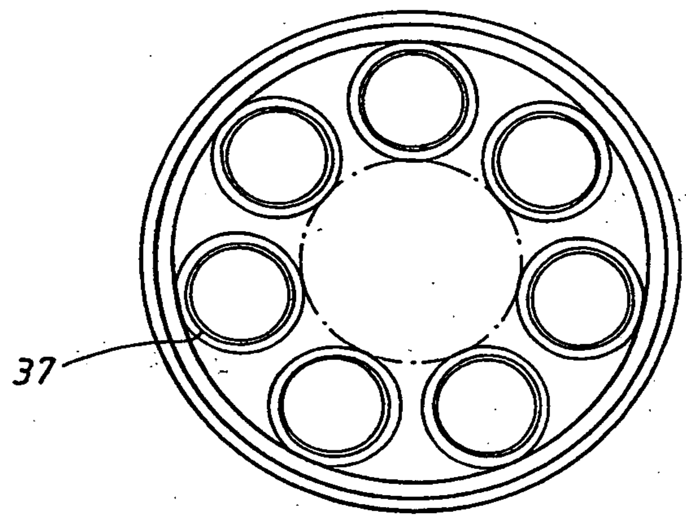


FIG. 3

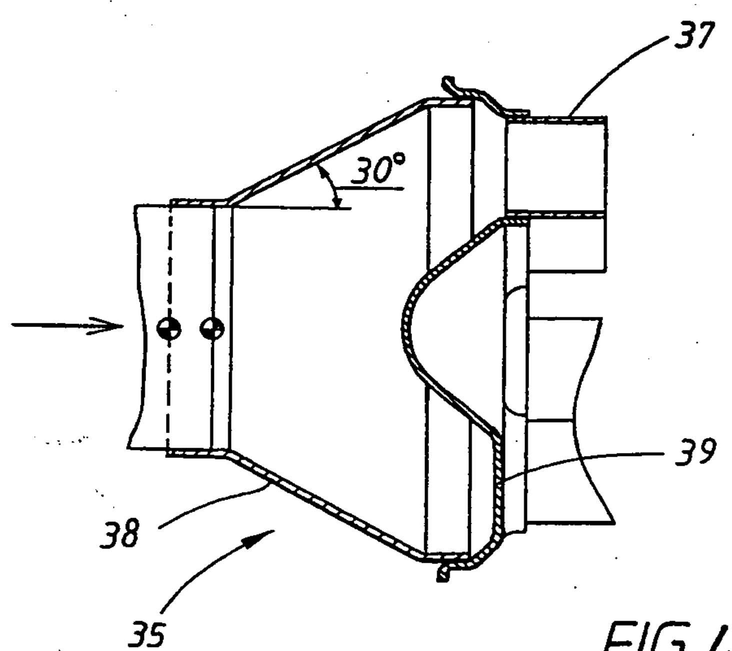


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/02090

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F01N 3/20
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 19706608 A1 (FORD GLOBAL TECHNOLOGIES INC.), 27 August 1998 (27.08.98), column 4, line 15 - line 66, figure 1, abstract --	1-8
Y	DE 4410022 A1 (SIEMENS AG), 5 October 1995 (05.10.95), column 2, line 42 - line 50, figure 3, abstract --	1-8
A	DE 29708011 U1 (SOLVAY VERWALTUNGS- UND VERMITTLUNGS GMBH), 8 October 1998 (08.10.98), figures 2-3, page 1, paragraph 2 - paragraph 3 --	2

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 March 2000	30-03-2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Johan Westerbergh/ELY Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/02090

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5595060 A (KAZUHIDE TOGAI ET AL), 21 January 1997 (21.01.97), column 31, line 55 - column 36, line 64, figure 2, abstract --	5-8
A	EP 0498598 A1 (TOYOTA JIDOSHA KABUSHIKI KAISHA), 12 August 1992 (12.08.92) --	1-4
P,X	DE 19746658 A1 (EMITEC GESELLSCHAFT FüR EMISSIONSTECHNOLOGIE MBH), 29 April 1999 (29.04.99), column 1, line 57 - column 3, line 23; column 3, line 64 - column 4, line 5; column 6, line 18 - line 63, figure 2, abstract --	1-2,8
P,A	DE 19731624 A1 (VOLKSWAGEN AG), 28 January 1999 (28.01.99), figure 1, claim 1, abstract -- --------	1-8

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/SE 99/02090

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19706608 A1	27/08/98	EP 0860595 A	26/08/98
DE 4410022 A1	05/10/95	NONE	
DE 29708011 U1	08/10/98	NONE	
US 5595060 A	21/01/97	DE 19517168 A	23/11/95
		JP 7305644 A	21/11/95
		KR 150432 B	01/10/98
		JP 7310534 A	28/11/95
		JP 8121147 A	14/05/96
EP 0498598 A1	12/08/92	DE 69202163 D,T	28/09/95
		JP 2884798 B	19/04/99
		JP 4255521 A	10/09/92
		US 5201802 A	13/04/93
		JP 2616262 B	04/06/97
		JP 4265414 A	21/09/92
DE 19746658 A1	29/04/99	AU 1228999 A	10/05/99
		WO 9920876 A	29/04/99
DE 19731624 A1	28/01/99	EP 0892158 A	20/01/99